MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

EEL2216 – CONTROL THEORY

(All sections / Groups)

4 MARCH 2016
9.00 a.m. - 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of **SEVEN** pages including cover page with **FOUR** questions only.

2. Answer **ALL** questions and print all your answers in the answer booklet provided.

3. All questions carry equal marks and the distribution of the marks for each question is given.

Question 1

(a) Find the ramp response for a system whose transfer function is given by

$$G(s) = \frac{s}{(s+4)(s+8)}.$$

[7 marks]

(b) Write the modeling equation in Laplace transform (assuming zero initial conditions) for the electrical network of Fig. 1.1. Obtain the transfer function $V_L(s)/V(s)$.

[6 marks]

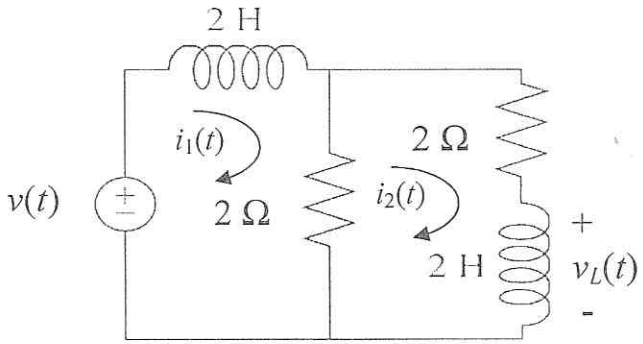

Fig. 1.1

(c) Derive the transfer function $T(s) = C(s)/R(s)$ of the signal flow graph shown in Fig. 1.2 by using Mason's rule.

[12 marks]

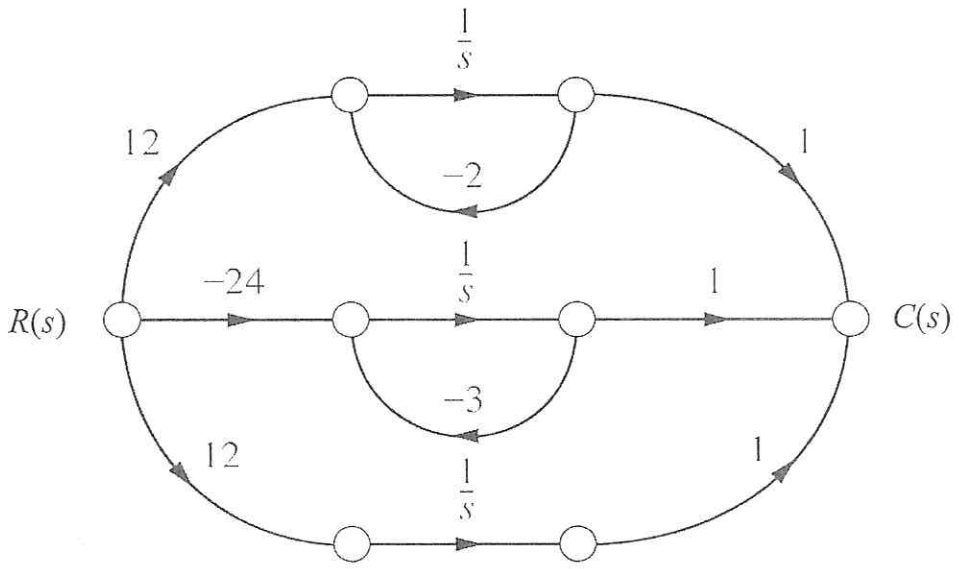

Fig. 1.2

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Question 2

(a) Consider a unity feedback system shown in Fig. 2.1. Evaluate if the system is underdamped, critically damped or overdamped.

[5 marks]

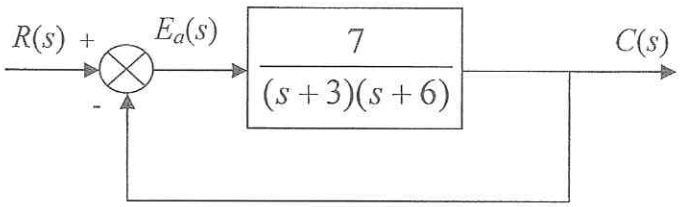

Fig. 2.1

(b) A unity feedback system has a forward path transfer function,

$$KG(s) = \frac{K(s+2)(s+1)}{(s-2)(s-1)}.$$

(i) List the starting and ending points of the root locus.

[4 marks]

(ii) Find the value of K for marginal stability and the corresponding values of the closed-loop poles.

[6 marks]

(iii) Calculate the break-away and break-in points of the root locus.

[6 marks]

(iv) Based on your answers in parts (i), (ii) and (iii) above, sketch the root locus.

[4 marks]

Continued...

Question 3

(a) State the Nyquist stability criterion.

[4 marks]

(b) Bode plot is a very useful graphical tool for the analysis and design of linear control systems. State two advantages of Bode plots over Nyquist plots.

[4 marks]

(c) Using Nyquist stability criterion, determine the stability of the closed-loop system shown in Fig. 3.1.

[17 marks]

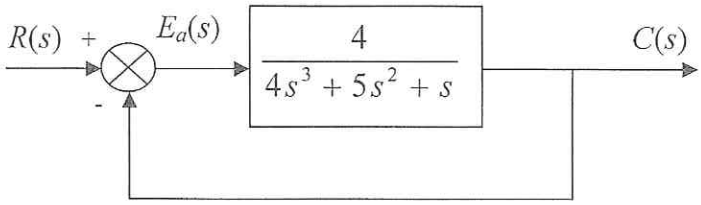

Fig. 3.1

Continued...

Question 4

(a) Proportional Integral (PI) controller can be realised by using a circuit with two or three operational amplifiers (op-amps). Construct a PI controller using two op-amps. State ONE (1) advantage and ONE (1) disadvantage of this implementation.

[7 marks]

(b) State the main function for each of the following compensators:

(i) Proportional Integral (PI)

(ii) Proportional Derivative (PD)

(iii) Proportional Integral Derivative (PID)

[3 marks]

(c) The unity feedback system shown in Fig. 4.1 has a PI controller $K(s)$ and a plant transfer function $G(s)$ given by

$$K(s) = K_p + \frac{K_I}{s}, \qquad G(s) = \frac{s}{(s+1)(s+2)(s+3)}$$

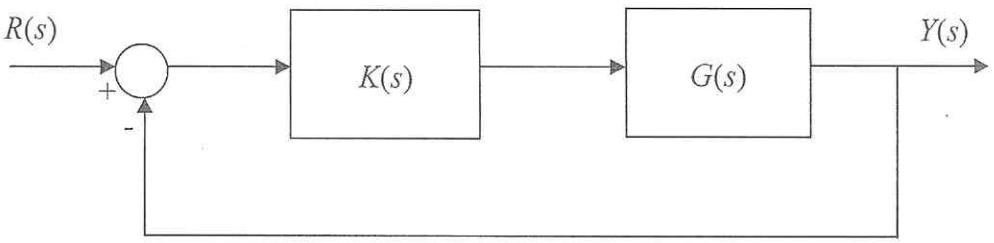

Fig. 4.1

Design the PI controller so that the following specifications are met:

- For a unit step input, the steady-state error is no more than 0.05.
- The system is stable (or marginally stable).

[15 marks]

Continued...

Appendix - Laplace Transform Pairs

$f(t)$	$F(s)$
Unit impulse $\delta(t)$	1
Unit step $1(t)$	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ $(n = 1, 2, 3, \ldots)$	$\frac{1}{s^n}$
t^n $(n = 1, 2, 3, \ldots)$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\frac{t^{n-1}}{(n-1)!}e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\frac{1}{(s+a)^n}$
$t^n e^{-at}$ $(n = 1, 2, 3, \ldots)$	$\frac{n!}{(s+a)^{n+1}}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$\sinh \omega t$	$\frac{\omega}{s^2-\omega^2}$
$\cosh \omega t$	$\frac{s}{s^2-\omega^2}$
$\frac{1}{a}(1-e^{-at})$	$\frac{1}{s(s+a)}$
$\frac{1}{b-a}(e^{-at}-e^{-bt})$	$\frac{1}{(s+a)(s+b)}$
$\frac{1}{b-a}(be^{-bt}-ae^{-at})$	$\frac{s}{(s+a)(s+b)}$
$\frac{1}{ab}\left[1+\frac{1}{a-b}(be^{-at}-ae^{-bt})\right]$	$\frac{1}{s(s+a)(s+b)}$

Continued...

Appendix - Laplace Transform Pairs (continued)

$\frac{1}{a^2}(1-e^{-at}-ate^{-at})$	$\frac{1}{s(s+a)^2}$
$\frac{1}{a^2}(at-1+e^{-at})$	$\frac{1}{s^2(s+a)}$
$e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$\frac{\omega_n}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin\omega_n\sqrt{1-\zeta^2}\,t$	$\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$
$-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t-\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{s}{s^2+2\zeta\omega_n s+\omega_n^2}$
$1-\frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n t}\sin(\omega_n\sqrt{1-\zeta^2}\,t+\phi)$ $\phi=\tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$	$\frac{\omega_n^2}{s(s^2+2\zeta\omega_n s+\omega_n^2)}$
$1-\cos\omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t-\sin\omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin\omega t-\omega t\cos\omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega}t\sin\omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t\cos\omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$
$\frac{1}{\omega_2^2-\omega_1^2}(\cos\omega_1 t-\cos\omega_2 t)\quad(\omega_1^2\neq\omega_2^2)$	$\frac{s}{(s^2+\omega_1^2)(s^2+\omega_2^2)}$
$\frac{1}{2\omega}(\sin\omega t+\omega t\cos\omega t)$	$\frac{s^2}{(s^2+\omega^2)^2}$

End of Paper